Inter-Layer Mixing for Improved SCR Performance

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Summary

Over 100 GW of selective catalytic reduction (SCR) systems have been and are being installed on large coal-fired utility boilers. The state of the art for multi-layer SCR systems provides for 90% NO_x reduction, while maintaining ammonia (NH_3) slip at levels below 2 ppm. NO_x reduction in excess of 90% would be desirable, if it could be achieved cost effectively.

An important SCR operating parameter is the NH_3/NO_x uniformity. Typically a catalyst vendor will specify that the uniformity must be characterized as having a coefficient of variation entering the first catalyst layer of less than 5%. However, as the flue gas proceeds through the layers, the NH_3/NO_x uniformity degrades such that the coefficient of variation of the NH_3/NO_x ratio entering the last layer can be on the order of 100%; and this limits the system's overall NO_x reduction performance. One approach to alleviating this limitation is to mix the flue gases in-between the catalyst layers, thus reducing the NH_3/NO_x ratio variation entering subsequent layers.

Under EPRI funding, a combined process model and physical cold flow model study has shown that mixing between catalyst layers to achieve more uniform NH_3/NO_x ratios can have a marked impact on SCR performance. This work has shown that inter-layer mixing has the potential of improving the NO_x control capabilities of large SCR systems by as much as 5 percentage points, while still keeping NH_3 slip levels below 2 ppm. Work to date on this new process has comprised two phases. The initial phase was an analytical study using a computer-based SCR process model to predict how much SCR performance could be improved by mixing flue gas between the layers of a multi-layer SCR system. The second-phase involved physical modeling and showed that inter-layer mixing could be accomplished using static and kinetic mixers.

The analytical study showed the following:

- The benefits of interlayer mixing do not depend on the number of catalyst layers in the SCR reactor.

- It was also found that it was not necessary to mix between all layers. In most instances it was only necessary to mix between one of the layers. Which layer, however, depends on the specific operating conditions.

- For an SCR reactor designed for 90% NO_x reduction with less than 2 ppm NH_3 slip, interlayer mixing can increase the NO_x reduction to in excess of 95% while maintaining NH_3 slip less than 2 ppm.

- The amount of mixing does not have to be significant. Reducing the coefficient of variation of the NH_3/NO_x ratio between two layers from 35% to 20% can lead to significant increases in SCR performance.

The physical cold flow model study showed that both static and dynamic mixers were effective in reducing the coefficient of variation of the NH_3/NO_x ratio. The dynamic mixers were the most successful, in that they were able to improve the variation of the NH_3/NO_x ratio from nominally 35% to under 20%. This level of mixing is sufficient to increase the NO_x reduction to over 95% while maintaining low NH_3 slip.

The physical cold flow model study also demonstrated the following:

- The amount of mixing achievable by a mixing configuration improves with an increase in the amount of mixing distance. Therefore, SCR reactors with extra space between the catalyst layers, or room for an additional layer, may benefit more from interlayer mixing, by merely taking advantage of the additional mixing length.

- It was found that it is easier to improve the NH_3/NO_x ratio uniformity if the baseline, or unmixed, variance is higher. This may indicate that it would be more advantageous, and effective, to mix between only the latter layers.

- Of the mixing devices tested, the dynamic mixers were not only the most effective in improving the coefficient of variance of the NH_3/NO_x ratio, but they demonstrated other advantages over the static mixers, in that they were easily installable, removable, and inexpensive, and they had the ability to be simply turned off when not needed.

In the summer of 2006, a pilot scale proof of concept test using dynamic mixing is planned to demonstrate the improvements in SCR performance gained with interlayer mixing.